OFFICE OF NAVAL RESEARCH
ANNUAL PROJECT REPORT

CONTRACT: N00014-96-1-0241
TITLE: High Speed, Numerically Superior Signal Processing Algorithms Using QRD & Delta Operator
PI: Dr. H. (Howard) Fan, University of Cincinnati
PERIOD: 1 October 1995 through 30 Sept. 1996

This period is the first annum under this new grant. Our efforts are focused on the following activities:

1. Continue to study the δ-operator based stability test algorithms, due to the importance f this subject. We have performed a sensitivity analysis, and have shown the lvantages of the δ-operator based stability tests developed by the PI under the revious grant (N00014-90-J-1017). Specifically, we have defined a new kind of ensitivity matrices and have shown that the δ-operator based tests have sensitivity natrices that approach those of the continuous-time tests as the sampling interval vanishes, whereas those of the traditional shift-operator based tests grow without bound under the same condition. This establishes the numerical superiority of the δ-operator based stability tests analytically. Submitted papers A1 and A2 in the attached publications report are summarizing this result. Another aspect is the singular case of the δ-operator based stability tests. Similar to the shift-operator based stability tests, the δ-operator tests developed so far are only for the regular case. They will fail in the singular case. Therefore, we have developed a stability test for the singular type I δ-Schur-Cohn test. We have also shown that the limit of this test as the sampling interval vanishes is a corresponding singular test in the continuous-time. Further, we have reconciled two seemingly different approaches in dealing with singularity type II, one in the shift-operator discrete-time and the other in the continuous-time, through the δ-operator test for singularity type II. Submitted paper A3 is for this result.

2. We have also studied the normalized lattice structure and its continuous-time limit. It turns out that, unlike any other filter structure, the normalized lattice has a continuous-time limit as the sampling interval vanishes. This explains the well-known good numerical properties of the normalized lattice. However, this limit does not realize an arbitrary stable transfer function in the continuous-time. We thus modified the normalized lattice so its limit can now realize an arbitrary stable transfer function in the continuous-time. Various aspects of stability of the newly modified normalized lattice are studied. The results are summarized in A4 of the attached publication/presentations report.

3. We have also begun to investigate the QRD-based recursive least squares (QRD-RLS) algorithm and its δ-operator version for adaptive signal processing. We have obtained a δ-operator based algorithm for off-line processing (non-recursive) and its continuous-time limit. Currently we are working on the recursive version. We are also looking into finite precision implementation aspect of the QRD and δ-QRD, in order to understand and study the numerical advantages offered by these algorithms.

4. Further work has also been done in the "generalized delta operator", in cooperation with the Swedish researchers at the Systems and Control Group, Uppsala University, Sweden. Particularly, we are interested in the limiting case where continuous-time autoregressive model parameters are to be estimated from the discrete-time data. Our previous work in using a modified least squares (LS) method resulted in Publication I1 of the attached publication/presentations report. In our current work we use the conventional LS method rather than the modified LS method, and then correct the resulting parameter bias at the last stage by a simple scaling. The advantage of the new approach is that, since the conventional LS method is used, we can now use

recursive algorithms to obtain computational savings. We have submitted a conference paper on this result so far. But more publication is on the way.

5. Blind equalization. This work was supported jointly by the AASERT program under Grant N00014-93-1-1032. We have constructed a new family of cost functions for blind equalization. Although not all convex, they all seem to be unimodal. Publication I2 in the attached publication/presentations report is one result. More work has been performed since then. We have tried to show the unimodality analytically, which proved to be very difficult. We are now working on the noise issue, and are also preparing a journal paper submission. On the other hand, we are also investigating the potential of using the subspace system identification methods in this problem. The results are very preliminary and will be reported subsequently.

6. During this period we also revised some of the previously submitted papers. This includes a finite precision paper using a stochastic differential equation approach (now accepted for publication), two δ-operator stability test papers (now also accepted for publication), and a paper analyzing conditioning of information matrices for δ-operator based algorithms. All these papers will be duly reported when they appear in the respective journals.

OFFICE OF NAVAL RESEARCH
PUBLICATIONS/PATENTS/PRESENTATIONS/HONORS REPORT
for
1 October 1995 through 30 Sept. 1996

Contract/Grant Number: N00014-96-1-0241

Contract/Grant Title: High Speed, Numerically Superior Signal Processing Algorithms Using QRD and Delta Operator

Principal Investigator: Dr. H. (Howard) Fan

Mailing Address: Dept. of Electrical & Computer Engineering and Computer Science
M.L. 30
University of Cincinnati
Cincinnati, OH 45221

Phone Number (with area code): (513) 556-4765

E-Mail Address: h.fan@uc.edu

a. Number of Papers Submitted to Refereed Journals but not yet published: 4

b. Number of Papers Published in Refereed Journals: 2

c. Number of Books or Chapters Submitted but not yet Published: 0

d. Number of Books or Chapters Published: 0

e. Number of Printed Technical Reports & Non-Refereed Papers: 0

f. Number of Patents Filed: 0

g. Number of Patents Granted: 0

h. Number of Invited Presentations at Workshops or Prof. Society Meetings: 0

i. Number of Presentation at Workshop or Prof. Society Meetings: 2

j. Honors/Awards/Prizes for Contract/Grant Employees: 1

k. Total number of Graduate Students and Post-Docs Supported at least 25%, on this contract/grant:

Grad Students 3 and Post Docs 0

How many of each are females or minorities? (These 6 numbers are for ONR's EEO/Minority Reports: minorities include Blacks, Aleuts Amindians, etc. and those of Hispanic or Asian extraction/ nationality. These Asians are singled out to facilitate meeting the varying report semantics re "under-represented").

[Grad Student Female ____
] [
] [Grad Student Minority ____
] [
] [Grad Student Asian e/n 3
] [
] [Post-Doc Female ____
] [
] [Post-Doc Minority ____
] [
] [Post-Doc Asian e/n ____

A. PAPERS SUBMITTED TO REFEREED JOURNALS

1. H. Fan, "On delta-operator Schur-Cohn zero-location tests for fast sampling," IEEE Trans. on Signal Processing, in review.

2. H. Fan, "Connection between stability tests of Middletown/Goodwin and Lev-Ari/Bistritz/Kailath," IEEE Trans. on Circuits and Syst., in review.

3. H. Fan, "Singular root distribution problem for delta-operator based real polynomials," Automatica, in review.

4. P. De and H. Fan, "Stable lattice filters and their continuous-time limits," IEEE Trans. Circuits and Systems, in review.

B. PAPERS PUBLISHED IN REFEREED JOURNALS

1. M. Doroslovacki and H. Fan, "Wavelet-based linear system modeling and adaptive filtering," IEEE Trans. Signal Processing, vol. 44, no. 5, pp. 1156-1167, May 1996.

2. Q. Li, H. Fan, and E. Karlsson, "A delta MYWE algorithm for parameter estimation of noisy AR processes," IEEE Trans. Signal Processing, vol. 44, no. 5, pp. 1300-1303, May 1996.

I. PRESENTATIONS AT PROFESSIONAL SOCIETY MEETINGS

1. T. Söderström, H. Fan, S. Bigi, and B. Carlsson, "Can a least-squares fit be feasible for modeling continuous-time auto-regressive processes from discrete-time data?" Proc. 34th IEEE Conf. on Decision and Control, vol. 2, pp. 1795-1800, New Orleans, Dec. 1995.

2. V. Shtrom and H. Fan, "Blind equalization: A new convex cost function," Proc. 1996 International Conference on Acoust., Speech, and Signal Processing, vol. 3, pp. 1779-1782, Atlanta, GA, May 1996.

J. HONORS/AWARDS/PRIZES FOR CONTRACT/GRANT EMPLOYEES

1. H. Fan, promoted to professor by the University of Cincinnati effective September 1, 1996.

K. GRADUATE STUDENTS SUPPORTED UNDER THE CRP FOR THIS PERIOD

1. P. De, Ph.D. candidate

2. G. Yan, Ph.D. candidate (partially supported)

3. Y. Zou, M.S. candidate (partially supported)

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	Oct. 28,1996	Annual, 10/1/95 - 9/30/96

4. TITLE AND SUBTITLE

High Speed, Numerically Superior Signal Processing Algorithms Using QRD & Delta Operator

5. FUNDING NUMBERS

N00014-96-1-0241

6. AUTHOR(S)

H. (Howard) Fan

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

University of Cincinnati
Dept. of ECECS, ML 30
Cincinnati, OH 45221

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Office of Naval Research
Attn.: Dr. Nick Bottka
800 North Quincy St.
Arlington, VA 22217-5660

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION / AVAILABILITY STATEMENT

Approved for Public Release

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

Several research topics related to the delta-operator have been studied. Firstly, for the delta-operator based efficient stability tests, the sensitivity issue and the singular cases have been studied. It is shown that the delta-operator based tests have much improved sensitivity than the traditional tests in the discrete-time. Unifying algorithms have also been developed for the singular cases. Secondly, the normalized lattice is further studied and modified so its continuous-time limit can realize an arbitrary transfer function. Various aspects of stability associated with the modified form are investigated. Thirdly, further results are obtained in the least-squares method using the "generalized delta operator". Other topics such as the blind equalization and the QRD based algorithms have also been studied.

14. SUBJECT TERMS

delta-operator, stability test, normalized lattice

15. NUMBER OF PAGES

4

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	SAR